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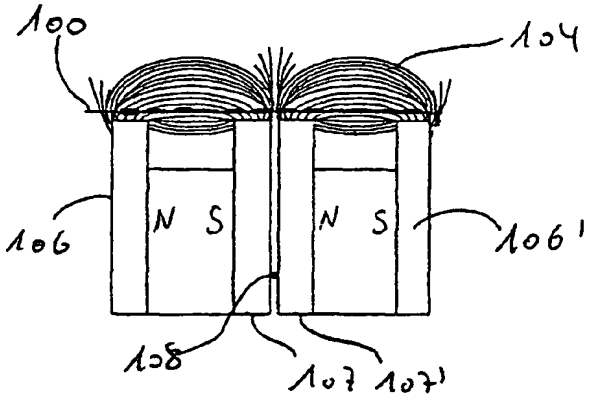
(54) Title: DIAPHRAGM TRANSDUCER



(57) Abstract: A new type of diaphragm transducer comprising magnets to provide magnetic field strength in a planar region and a planar diaphragm located in the said planar region. The diaphragm has a plurality of conductors on its planar surface for inducing electromagnetic forces acting on these conductors in said planar region when current flows through said conductors. The magnets are arranged in magnetic interaction with a magnetically conducting material, preferably soft iron, to conduct magnetic field from said magnets to said planar region.

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Registration Number: 27997

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Copy for the Elected Office (EO/US)

PCT/DK00/00504

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

PATRADE A/S
Fredens Torv 3A
DK-8000 Aarhus C
DANEMARK

Date of mailing (day/month/year)
09 August 2001 (09.08.01)

Applicant's or agent's file reference
P9961PC00

IMPORTANT NOTIFICATION

International application No.
PCT/DK00/00504

International filing date (day/month/year)
13 September 2000 (13.09.00)

1. The following indications appeared on record concerning:

☐ the applicant ☐ the inventor ☒ the agent ☐ the common representative

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State of Residence:
Telephone No.: 45 7020 3770
Facsimile No.: 45 7020 3771
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person ☐ the name ☒ the address ☐ the nationality ☐ the residence

Name and Address
PATRADE A/S
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State of Nationality:
State of Residence:
Telephone No.: +45 7020 3770
Facsimile No.: +45 7020 3771
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☒ the receiving Office
☐ the International Searching Authority
☒ the International Preliminary Examining Authority
☐ the designated Offices concerned
☒ the elected Offices concerned
☐ other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer
Beate Giffo-Schmitt

Telephone No.: (41-22) 338.83.38

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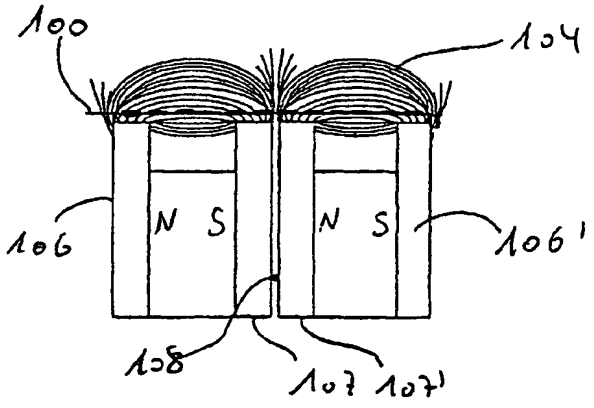


(57) Abstract: A new type of diaphragm transducer comprising magnets to provide magnetic field strength in a planar region and a planar diaphragm located in the said planar region. The diaphragm has a plurality of conductors on its planar surface for inducing electromagnetic forces acting on these conductors in said planar region when current flows through said conductors. The magnets are arranged in magnetic interaction with a magnetically conducting material, preferably soft iron, to conduct magnetic field from said magnets to said planar region.

WO 01/20949 A1

Diaphragm transducer

The present invention relates to a diaphragm transducer as described in the preamble of claim 1.

As loudspeakers, mainly two types are common. The one type comprises an annular coil disposed in a transverse magnetic field, where the coil is connected to a diaphragm, usually conical in shape. Current flowing through the coil results in a force moving the diaphragm. The second type comprises a planar diaphragm, where conductors are positions on the planar surface. A magnetic assembly behind or at the sides of the membrane result in displacement of the membrane, when current flows through the conductors.

It is well known, that the second type of loudspeaker is more expensive to manufacture as compared to the first type and the efficiency is lower. However, the quality of the emitted sound is much better in the second type, as it does not suffer from distortions of the membrane to the same extend as the first type.

An example of a loudspeaker with a planar diaphragm transducer is described in US patent no. 5,195,143. With reference to a drawing in that reference, which is reproduced in FIG. 1a, a woofer diaphragm 100 is located in front of an assembly of magnets 102 where magnetic field lines 104 propagate between corresponding north poles, N, and south poles, S. In order to produce proper sound, the diaphragm 100 has to move transversely to the plane of the diaphragm, which requires magnetic field lines 104 which are parallel to the plane and normal to the conductors on the diaphragm. However, as can be seen from FIG. 1a, a large portion of indicated field lines 104, are normal and not parallel to the diaphragm 100, resulting in low efficiency of the loudspeaker and distortion at higher currents.

Meanwhile, further study of the problem has shown, that the magnetic field lines 104', actually, do not propagate as shown on FIG. 1a, but rather propagate as shown in FIG. 1b, which explain the low efficiency of this type of loudspeaker, as the majority of

magnetic field line propagate transversely to the diaphragm plane, which is inappropriate.

As shown in FIG. 2a, according to prior art, it is possible to arrange magnets 102 such that the magnetic field lines are more parallel to the diaphragm 100, for example by placing the diaphragm 100 between a north and a south poles, where the diaphragm is normal to the surface of the poles. This arrangement, however, is only suitable for small diaphragms because of the required narrow space between the poles. Therefore, it is only used for loudspeakers in the high frequency regime and not for woofers. It is generally assumed for this arrangement, as shown in FIG. 2a, that the field lines 104 propagate from the left north pole of the arrangement to the right south pole.

However, study of this arrangement has shown that the field lines propagate as indicated in FIG. 2b, which illustrates the insufficiency of this arrangement. The field is very weak at the centre of the arrangement, and placing the diaphragm off-centre as shown in FIG. 2b results in field lines not parallel with the diaphragm.

A number of attempts have been undertaken to improve this type of loudspeakers, where the main effort has been put into the shaping of the magnetic field in the region in which the diaphragm is moved. However, no suitable solution has yet been found, notwithstanding the fact that this principle for loudspeakers has been existing for a long time.

It is an object of the invention to provide a diaphragm transducer of the above mentioned second type with a higher efficiency than known systems. It is a further object of the invention to provide a transducer with higher efficiency which is also cheap and easy to manufacture.

This object is achieved with a diaphragm transducer as mentioned by way of introduction which is characterised as described in the characterising part of claim 1.

Though ferromagnetic material as soft iron is used in the above mentioned first type of loudspeaker with an annular coil, this solution has never been envisaged in connection with loudspeakers of the second type. It is a very simple solution because the shaping of a magnetic field is much easier with ferromagnetic material than with magnets. Magnetic field lines are changed with respect to their direction when traversing soft iron because the magnetic reluctance in soft iron is much lower than in air.

In the following, soft iron will be used as a synonym for a magnetically conducting material. However, the magnetically conducting material can also be other material than soft iron with analogue properties and not being a permanent magnet. Possible other materials are iron-silicon, Permalloy, or iron-oxides.

According to further study of the invention, it has turned out, that it is possible to achieve an approximately constant magnetic field in the planar region where the diaphragm is located.

Shaping of the magnetic field can be achieved by applying plates of soft iron between which permanent magnets are located. One edge of each of said plates constitutes a magnetic pole in said configuration. For example, an arrangement can comprise three poles, two outer poles of equal polarity and one inner pole of opposite polarity.

The intensity of the magnetic field depends on the field strength of the magnets that are placed between the soft iron plates. But as the conduction of the magnetic field lines from the magnets, through the soft iron plates, and to the diaphragm is efficient, the invention opens the possibility to achieve high field strengths in the planar region even with relatively weak and cheap magnets. That has as a consequence, that this type of loudspeaker can be produced much cheaper than hitherto and for a price that can compete with the price for loudspeakers with annualar coils. Therefore, a large number of people, that could not afford this type of loudspeaker before, will be able to enjoy a clearer and more differentiated sound of music in their homes.

Surprisingly, it has turned out, as intense studies have shown, that it is a great advantage, if the inner poles located between the outer poles are arranged in pairs with a distance between the two plates constituting said pair. As compared with single inner poles, the magnetic field in the plane in front of the double poles is much more constant in strength and direction.

Because of the magnetic field in the planar region can be shaped to be approximately constant, the conductors on the diaphragm can easily be oriented and connected such that, when current flows through those conductors, the electromagnetic forces acting on the conductors in the planar region are approximately in the same direction normal to the plane of the diaphragm. This is the ideal case, but as the introductory discussion showed, that this has by far not been achieved in systems according to prior art.

Even higher field strengths can be achieved when the field is allowed to vary with a small amount. Small field strength variations can be adjusted for by placing the conductors on the diaphragm with varying mutual distances and directions.

To achieve a better performance of a transducer according to the invention, the diaphragm in a transducer may have a ferromagnetic magetisable layer. The layer can be part of the diaphragm material or be applied as a coating.

According to prior art, ferromagnetic magnetisable material as ferric oxide, Permalloy or soft iron has been used on annular coils in loudspeakers of the first type, for example in UK patent application GB 2,137,047 or in European patent application EP 587 910. The effect in these papers was damping and increasing the efficiency. For the above mentioned second type of loudspeaker, it has not been recognised that an improvement can be achieved.

However, as with the soft iron plates, a magnetically conducting layer in or on the diaphragm, for example a coating with soft iron, conducts the field lines along the diaphragm. The result is an increased number of field lines parallel with the diaphragm enhancing the efficiency of the transducer.

A soft iron coating on the diaphragm should be very thin and does, therefore, not conflict with the aim that the transducer diaphragm should have a very low mass. Once accelerated because of the current through the conductor in the magnetic field, a diaphragm with a higher mass will be harder to stop than a diaphragm with a lower mass. This might result in an overshooting of the diaphragm at peak currents with a result of sound distortions. A damping of the diaphragm may be achieved with the ferromagnetic material on the diaphragm. As the diaphragm moves in the magnetic field, the magnetic field changes causing a different magnetisation of the coating. The change in the magnetisation has the effect of damping the motion of the membrane, especially at large excursions. The damping ability is dependant on the magnetic hysteresis of the ferromagnetic material. Soft iron has a very low hysteresis, while Permalloy has a larger hysteresis. Which material is the best depends on the actual construction of the diaphragm transducer, especially, whether it is designed to work at higher or lower frequencies. As a rule of thumb, it should be mentioned here, however, that the lower the working frequency of the transducer, the higher a damping is needed.

The invention will be described further with reference to the drawing where
FIG. 1 illustrates the principle of a planar transducer according to prior art,
FIG. 2 illustrates the principle of a different transducer according to prior art,
FIG. 3 illustrates the principle of diaphragm transducer according to the invention,
FIG. 4 is a schematic view diaphragm transducer according to the invention.

FIG. 3 shows a diaphragm transducer according to the invention. Two magnets 102 with corresponding north poles, N, and south poles, S, are arranged in magnetic interaction with plates of soft iron 106. Each magnet 102 can consist itself of a number of smaller magnets acting in combination. The shown arrangement comprises three magnetic poles, two outer poles 106 and 106' of equal polarity, N, and an inner pole 107 of opposite polarity, S.

The construction as shown in FIG. 3 has a number of advantages. First, magnets are arranged behind the diaphragm and not beside the diaphragm. Therefore be built in a more narrow and more aesthetic design than hitherto. The necessary mass of the magnets 102 is stored behind the diaphragm 100. Second, to achieve a high field strength, relatively large magnets 102 or many magnets in combination can be used. thus, it is possible to achieve high field strengths even with magnets 102 that are low in production cost, which results in a low production cost of the transducer itself. Third, shaping of the field in the planar region of the diaphragm is relatively easy. To shape the field at the diaphragm, only the plates 106, 106', 107 have to be shaped, which is far more easy than shaping eventually brittle magnets 102. Fourth, assembly of the magnetic arrangement is easy and quick once the plates 106, 106', 107 are shaped.

FIG 4a. shows the transducer according to the invention in an exploded view. The diaphragm 100 is equipped with conductors 108 that are mutually connected, for example in a spiral arrangement as indicated on the figure. Current is applied to the conductors by appropriate connectors 110. The diaphragm is supported by a frame 114 of damping material, for example foam polymer. The structural support frame 116 of a rigid material secures a proper positioning of the magnets 102 and soft iron plates 106, 106', 107 with respect to the diaphragm 100.

A drawing of the assembly is shown in FIG. 4b through 4e, where FIG. 4b is a front view, FIG. 4c is a side view, FIG. 4d is a back view, and FIG. 4e is a view along the cut A-A as indicated on FIG. 4b. It can be seen, that only the longitudinal parallel conductors 108 are within the planar region 118 where the magnetic field has a high strength.

An alternative construction for a transducer according to the invention is achieved by fixing the diaphragm only at its end 112, 112', whereby the polymer support 114 can be omitted.

As described before, and illustrated in FIG. 5a, it has turned out that it is a great advantage, if the inner pole located between the outer poles is arranged in pairs 107,107'

with a distance 108 between the two plates 107, 107' constituting that pair. As compared with single inner poles, the magnetic field in the plane in front of the double poles 107, 107' is much more constant in strength and direction, which has been confirmed by experiment, but has not yet been completely understood.

The magnetic field 104 lines are in reality much more parallel with the diaphragm 100 than those drawn on figure 5a, as the field lines on the figure only serve for illustration.

In analogy to the arrangement in FIG. 5a, another arrangement with a plurality of pairs of poles is shown in FIG. 5b.

The diaphragm is equipped with a number of conductors 108. In front of the inner poles 107, 107', the conductor 108, 108' have approximately the same distance as the plates 107, 107'. For a high frequency loudspeaker, this distance is between 0.1 and 3 mm, preferably between 0.3 and 1.5 mm and mostly preferred between 0.4 and 0.6 mm.

CLAIMS

1. Diaphragm transducer comprising
- magnets to provide magnetic field strength in a planar region,
- a planar diaphragm located in said planar region, said diaphragm having a plurality of conductors on its planar surface for inducing electromagnetic forces acting on theses conductors in said planar region when current flows through said conductors,
- characterised in that
- said magnets are arranged in magnetic interaction with a magnetically conducting material, where the magnetically conducting material is not a permanent magnet, to conduct magnetic field from said magnets to said planar region.

2. Diaphragm transducer according to claim 1, characterised in that said magnetically conducting material is soft iron

3. Diaphragm transducer according to claim 1 or 2, characterised in that said magnetic field in said planar region is approximately constant.

4. Diaphragm transducer according to claim 1 - 3, characterised in that said magnetically conducting material is configured as plates, between which permanent magnets are located, where one edge of each of said plates constitutes a magnetic pole in said configuration.

5. Diaphragm transducer according to claim 4, characterised in that the number of poles are at least three with two outer poles and at least one inner pole.

6. Diaphragm transducer according to claim 5, characterised in that said number of inner poles located between the outer poles is at least two, where said inner poles are arranged in pairs of poles with a distance between the two plates constituting said pair.

7. Diaphragm transducer according to claim 6, characterised in that said distance between the two plates constituting a pair of poles, is between 0.1 and 3 mm, preferably between 0.3 and 1.5 mm and preferably between 0.4 and 0.6 mm.

8. Diaphragm transducer according to claim 1 - 7, characterised in that said conductors are oriented and connected such that, when current flows through said conductors, said electromagnetic forces acting on said conductors in said planar region are approximately in the same direction.

9. Diaphragm transducer to claim 1 - 8, characterised in that said diaphragm comprises a magnetically conducting layer.

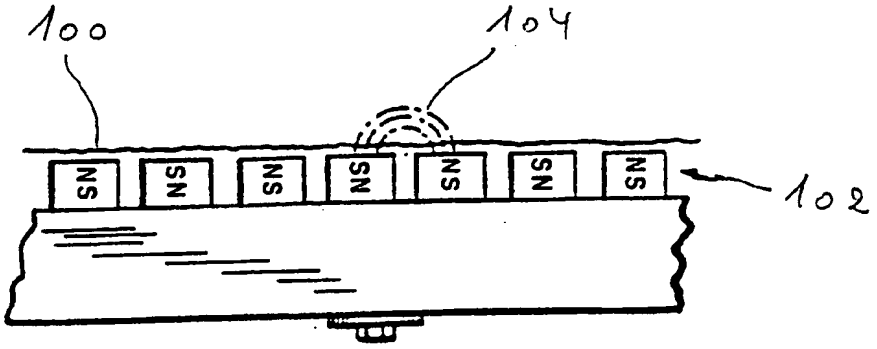
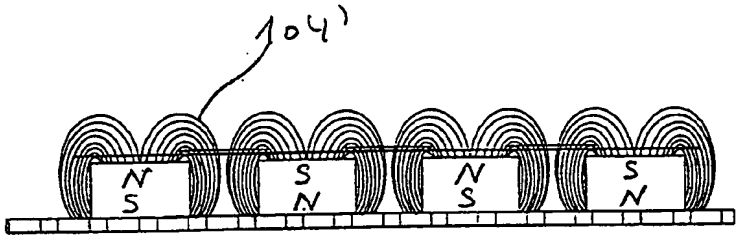
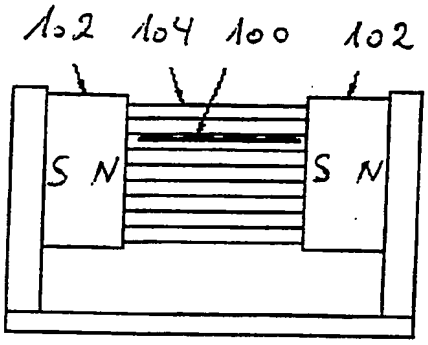


FIG. 1a prior art

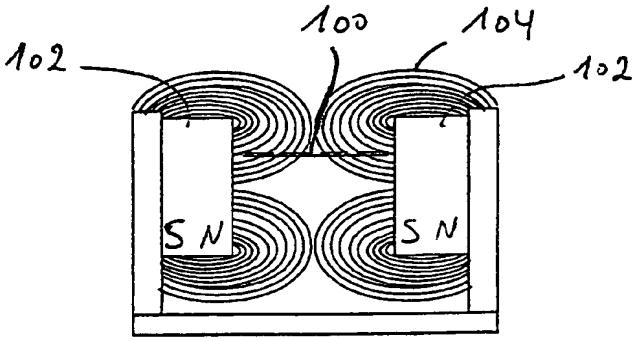


prior art

FIG. 1b



Prior art.
FIG. 2a



prior art
FIG. 2b

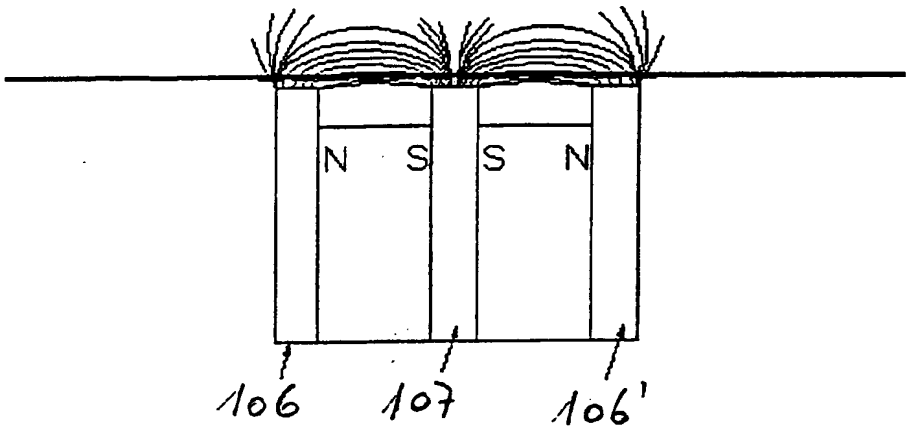


FIG. 3

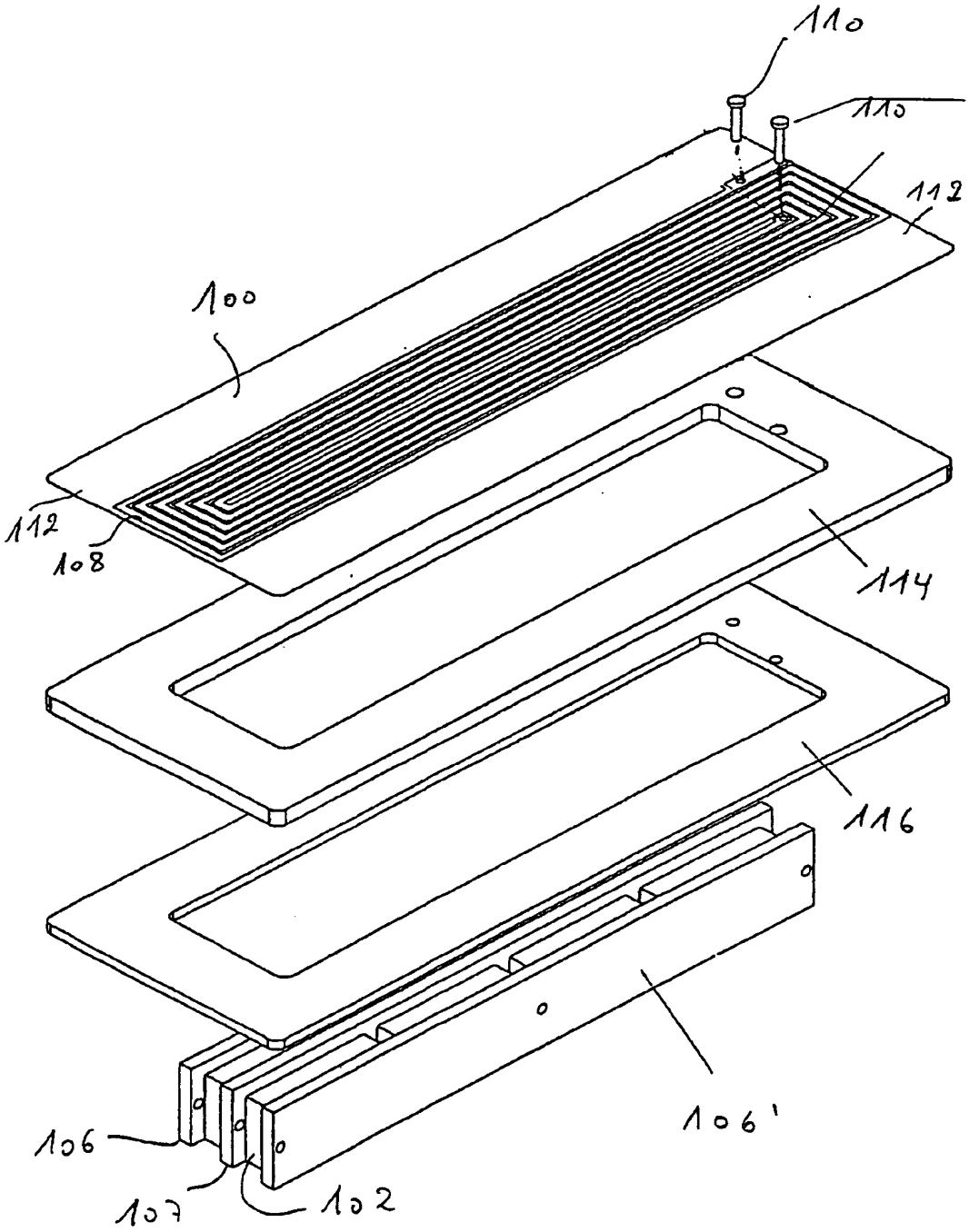


FIG. 4a

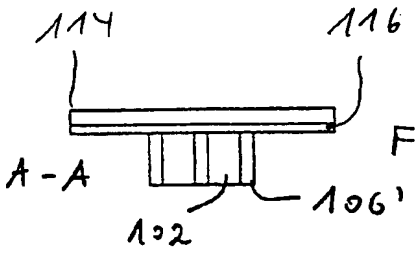


FIG. 4e

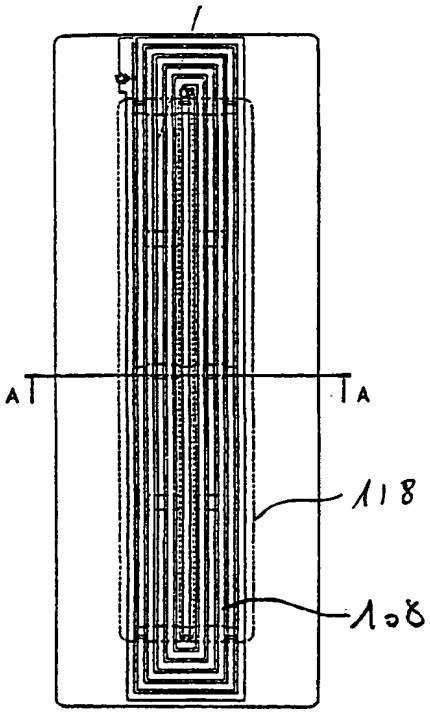


FIG. 4b

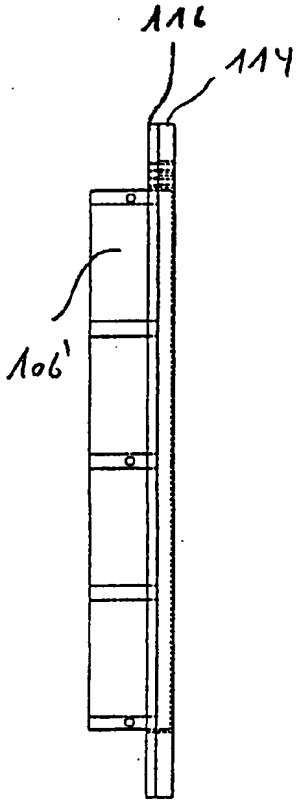


FIG. 4c

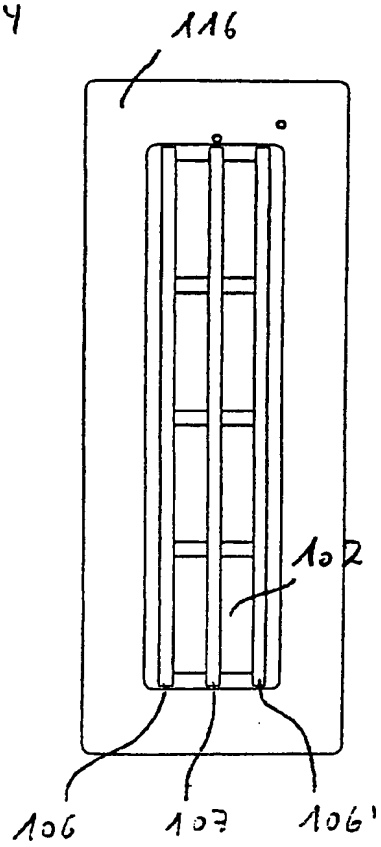


FIG. 4d

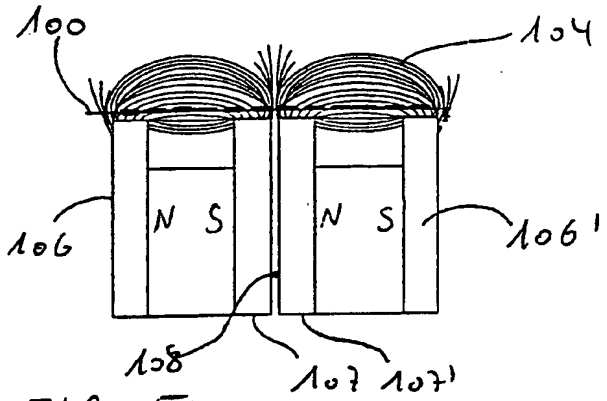


FIG. 5a

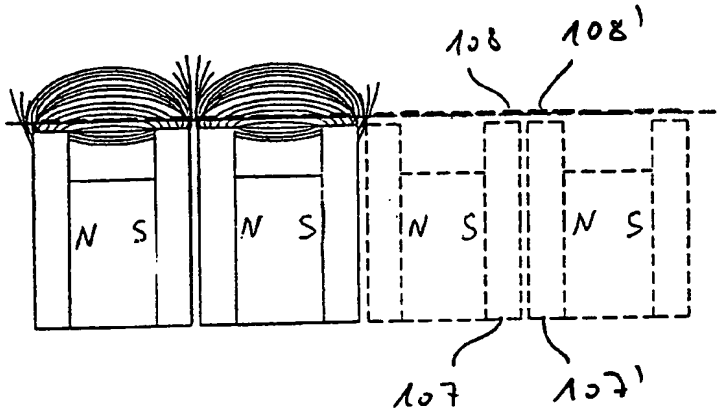


FIG. 5b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 00/00504

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04R 7/00, H04R 9/00, H04R 9/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4491698 A (LARSON ET AL.), 1 January 1985 (01.01.85), page 6, line 13 - line 25	1,3-5,8
Y		2,6,9
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Y	US 4354066 A (NECOECHEA), 12 October 1982 (12.10.82), page 5, line 26 - line 28; page 5, line 18 - line 24	2,6
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Y	US 5297214 A (BRUNEY), 22 March 1994 (22.03.94), page 6, line 10 - line 14	9
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A	US 5627903 A (PORRAZZO), 6 May 1997 (06.05.97)	1-9
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 December 2000	20 -12- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Mariana Eddin/OGU Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 00/00504

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9820705 A1 (CERWIN VEGA, INC.), 14 May 1998 (14.05.98)	1-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

04/12/00

International application No.
PCT/DK 00/00504

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4491698 A	01/01/85	AT 36924 T	15/09/88
		AU 563312 B	02/07/87
		AU 1777783 A	16/01/84
		BR 8307405 A	17/07/84
		CA 1213032 A	21/10/86
		DE 3377888 D	00/00/00
		EP 0112383 A,B	04/07/84
		SE 0112383 T3	
		EP 0262406 A	06/04/88
		US 4703510 A	27/10/87
		WO 8400093 A	05/01/84
US 4354066 A	12/10/82	EP 0098895 A	25/01/84
US 5297214 A	22/03/94	US 4939784 A	03/07/90
		US 5148493 A	15/09/92
US 5627903 A	06/05/97	AU 1213299 A	22/04/99
		AU 7927094 A	01/05/95
		CA 2173580 A	13/04/95
		EP 0748576 A	18/12/96
		JP 9504921 T	13/05/97
		US 6137891 A	24/10/00
		WO 9510166 A	13/04/95
WO 9820705 A1	14/05/98	AU 5247398 A	29/05/98
		AU 5252898 A	29/05/98
		US 6111970 A	29/08/00
		WO 9820703 A	14/05/98

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P9961PC00		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/DK00/00504	13/09/2000	14/09/1999
International Patent Classification (IPC) or national classification and IPC H04R7/00		
Applicant REEN.AUDIO APS et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 8 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
29/03/2001	17.12.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Aquilani, D Telephone No. +49 89 2399 7981

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/DK00/00504

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1,4-6	as published			
3	as received on	29/03/2001	with letter of	26/03/2001
2,2a,7	as received on	15/09/2001	with letter of	13/09/2001

Claims, No.:

1-10	as received on	15/09/2001	with letter of	13/09/2001

Drawings, sheets:

1/6-5/6	as published			
6/6	as received on	08/10/2001	with letter of	08/10/2001

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   ☐ the language of publication of the international application (under Rule 48.3(b)).
   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ The statement that the information recorded in computer readable form is identical to the written sequence

listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-10
	No:	Claims	
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-10
Industrial applicability (IA)	Yes:	Claims	1-10
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item V

Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents cited in the search report:

   D1: US 5297214
   D2: US 4354066
   D3: US 4491698
   D4: US 5627903

2. The document D1 is regarded as being the closest prior art to the subject-matter of claim 1, and insofar as this claim can be understood (see Section VIII), this document shows the following features thereof (using the wording of claim 1, the references in parentheses applying to D1 document):

   a diaphragm transducer comprising:
   - a planar diaphragm *(40)*,
   - magnets *(38)* to provide magnetic field strength through said planar diaphragm,

   wherein:
   - said magnets are in magnetic interaction with a magnetically conducting material *(36)*,
   - said magnets are arranged to face one side of said planar diaphragm (fig. 1)
   - said diaphragm *(40)* have a plurality of conductors (46, 48) on its planar surface for inducing electromagnetic force acting on said conductors (46, 48) when current flows through said conductors,
   - said conductors *(46, 48)* on said diaphragm *(40)* are arranged in a pattern in relation to said magnetic field strength through said diaphragm *(40)*, said relation being such that said electromagnetic force acting on said conductors *(46, 48)* is directed substantially normal to said surface of said planar diaphragm *(see col. 7, lines 5-11: the interaction between the current flowing in the conductors and the magnetic field generates a force which causes the diaphragm substantially to move along the excursion direction. Such "excursion direction" is normal to the planar surface of the diaphragm, as outlined in col. 7, lines 24-28).*

3. The subject-matter of claim 1 therefore differs from this known D1 in that:

3.1 the magnetically conducting material conducts the magnetic field from said magnets to said planar region

3.2 the magnetically conducting material is not a permanent magnet

4. Due to the distinguishing feature 3.1 with respect to the closest prior art, the subject-matter of claim 1 achieves that the magnetic field lines orientation is closer to the ideal case, which would require the magnetic field lines being parallel to the diaphragm plane and normal to the conductors on the diaphragm (see Application's description, pag.1, lines 24-25).

5. Therefore, the technical problem solved by the subject-matter of the claim may be regarded as how to conveniently orientate the lines of a magnetic field generated by permanent magnets.

6. However it is matter of standard design practice to use magnetically conducting material to orientate and extend the magnetic field lines (D1 rigid sheet 36; D2, fig. 10, poles 29 and 27 or D3, fig. 2, poles 44 and 46 are examples of such an arrangement).

7. The skilled person, having to solve the cited technical problem, would therefore apply his own common knowledge and arrive to the solution disclosed by claim 1 without the exercise of an inventive step (Art. 33(3) PCT).

8. The use of not permanent magnet (distinguishing feature 3.2) is just a mere design option.

9. As far as the application can be at the present understood, dependent claims 2-6 do not appear to contain any additional features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT with respect inventive step, the reasons being as follows:

9.1 The additional steps/features of claims 2 are known from D1(col. 6, lines 10-38).

9.2 The additional steps/features of claims 3 appear to be a mere design option.

9.3 D3 anticipates the additional steps/features of claims 3-6 (fig.1; in particular, the "distance" mentioned in claim 6 can be individuated in the gaps between the elongated steel poles 44, 46 not containing the projections P).

9.4 The additional steps/features of claims 7 appear to be a mere design option.

9.5 The additional steps/features of claims 8, 10 appear to be a mere design option *(the use of soft iron or Permalloy as magnetic conducting material is well known in the art, see, for example, description pag. 4, lines 21-27)*.

9.6 The additional steps/features of claims 9 appear to be known from D4 (col.9, lines 29-35).

10. Therefore a person skilled in the art would provide these features/steps with corresponding effect to a method/apparatus as known from document D1 without the exercise of inventive skills.

Re Item VII

Certain defects in the international application

11. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D4 is not mentioned in the description, nor are these documents identified therein.

Re Item VIII

Certain observations on the international application

12. It is clear from the description on pages 1, lines 23-25 that the following feature is essential to the definition of the invention:

(1) the magnetic field lines have to comprise a component parallel to the diaphragm plane.

As a matter of fact, if field lines were normal to said plane, there would be no possible arrangement (pattern) for the conductors 108 to produce an electromagnetic force

substantially normal to said surface, as it is claimed.

Since independent claim 1 does not contain this feature it does not meet the requirement following from Article 6 PCT taken in combination with Rule 6.3(b) PCT that any independent claim must contain all the technical features essential to the definition of the invention.

13. The embodiment of the invention shown in figures 3, 4a-e, 5a-b do not fall within the scope of the claim 1 since the magnets 102 are not arranged on one side of the planar diaphragm (100), but their are located on a different structure, facing one side of the planar diaphragm. This inconsistency between the claim and the description leads to doubt concerning the matter for which protection is sought, thereby rendering the claim 1 unclear (Article 6 PCT).

14. The embodiment of the invention described on pag. 5, line 25 - pag. 6, line 11 and shown in figures 3, 4a-e, 5a-b do not fall within the scope of the claim 10 since the plates 106, 106', 107, 107' are not part of the magnetically conducting layer which is comprised in the planar diaphragm as claimed in claim 9. This inconsistency between the claim and the description leads to doubt concerning the matter for which protection is sought, thereby rendering the claim 10 unclear (Article 6 PCT).

magnetic field line propagate transversely to the diaphragm plane, which is inappropriate.

As shown in FIG. 2a, according to prior art, it is possible to arrange magnets 102 such that the magnetic field lines are more parallel to the diaphragm 100, for example by placing the diaphragm 100 between a north and a south poles, where the diaphragm is normal to the surface of the poles. This arrangement, however, is only suitable for small diaphragms because of the required narrow space between the poles. Therefore, it is only used for loudspeakers in the high frequency regime and not for woofers. It is generally assumed for this arrangement, as shown in FIG. 2a, that the field lines 104 propagate from the left north pole of the arrangement to the right south pole.

However, study of this arrangement has shown that the field lines propagate as indicated in FIG. 2b, which illustrates the insufficiency of this arrangement. The field is very weak at the centre of the arrangement, and placing the diaphragm off-centre as shown in FIG. 2b results in field lines not parallel with the diaphragm.

A number of attempts have been undertaken to improve this type of loudspeakers, where the main effort has been put into the shaping of the magnetic field in the region in which the diaphragm is moved. In US patent no. 4 491 698, a diaphragm transducer is disclosed having a planar diaphragm with vanes extending perpendicular from the diaphragm and into a magnetic arrangement behind the diaphragm. However, no suitable solution has yet been found, notwithstanding the fact that this principle for loudspeakers has been existing for a long time.

In US patent no. 4 354 066, a non-planar, rigid-diaphragm transducer is disclosed whith a coil for interaction with a magnetic field, where the coil support is outside the diaphragm. In US patent 5 297 214 a loudspeaker is disclosed with a planar diaphragm having thin conductors thereon. The magnetic field is provided by an arrangement of permanent magnets on one side of the diaphragm.

It is an object of the invention to provide a diaphragm transducer of the above mentioned second type with a higher efficiency than known systems. It is a further object of the invention to provide a transducer with higher efficiency which is also cheap and easy to manufacture.

This object is achieved with a diaphragm transducer as mentioned by way of introduction which is characterised as described in the characterising part of claim 1.

Using ferromagnetic material as soft iron in connection with loudspeakers of the second type is a very simple solution because the shaping of a magnetic field is much easier with ferromagnetic material than with magnets. Magnetic field lines are changed with respect to their direction when traversing soft iron because the magnetic reluctance in soft iron is much lower than in air.

In the following, soft iron will be used as a synonym for a magnetically conducting material. However, the magnetically conducting material can also be other material than soft iron with analogue properties and not being a permanent magnet. Possible other materials are iron-silicon, Permalloy, or iron-oxides.

According to further study of the invention, it has turned out, that it is possible to achieve an approximately constant magnetic field in the planar region where the diaphragm is located.

Shaping of the magnetic field can be achieved by applying plates of soft iron between which permanent magnets are located. One edge of each of said plates constitutes a magnetic pole in said configuration. For example, an arrangement can comprise three poles, two outer poles of equal polarity and one inner pole of opposite polarity.

The intensity of the magnetic field depends on the field strength of the magnets that are placed between the soft iron plates. But as the conduction of the magnetic field lines from the magnets, through the soft iron plates, and to the diaphragm is efficient, the invention opens the possibility to achieve high field strengths in the planar region even with relatively weak and cheap magnets. That has as a consequence, that this type of loudspeaker can be produced much cheaper than hitherto and for a price that can compete with the price for loudspeakers with annualar coils. Therefore, a large number of people, that could not afford this type of loudspeaker before, will be able to enjoy a clearer and more differentiated sound of music in their homes.

with a distance 103 between the two plates 107, 107' constituting that pair. As compared with single inner poles, the magnetic field in the plane in front of the double poles 107, 107' is much more constant in strength and direction, which has been confirmed by experiment, but has not yet been completely understood.

The magnetic field 104 lines are in reality much more parallel with the diaphragm 100 than those drawn on figure 5a, as the field lines on the figure only serve for illustration.

In analogy to the arrangement in FIG. 5a, another arrangement with a plurality of pairs of poles is shown in FIG. 5b.

The diaphragm is equipped with a number of conductors 108. In front of the inner poles 107, 107', the conductor 108, 108' have approximately the same distance 103 as the plates 107, 107'. For a high frequency loudspeaker, this distance is between 0.1 and 3 mm, preferably between 0.3 and 1.5 mm and mostly preferred between 0.4 and 0.6 mm.

CLAIMS

1. Diaphragm transducer comprising

- a planar diaphragm (100),
- magnets (102) arranged to provide magnetic field (104) strength through said ~~in a~~ planar ~~region~~diaphragm (100),
- said magnets (102) being in magnetic interaction with a magnetically conducting material (106, 106', 107, 107'),
- said magnets (102) being arranged on one side of said diaphragm (100),

~~- said magnets are arranged behind said planar diaphragm in magnetic interaction with a magnetically conducting material, where the magnetically conducting material is not a permanent magnet, to conduct magnetic field from said magnets to said planar region,~~ - said diaphragm (100) having a plurality of conductors (108) on its planar surface for inducing electromagnetic force acting on said conductors (108) when current flows through said conductors (108),

characterised in ~~that~~

- that said magnets (102) are in magnetic interaction with a magnetically conducting material (106, 106', 107, 107') to conduct magnetic field (104) strength from said magnets (102) to said diaphragm (100),
- that said magnetically conducting material (106, 106', 107, 107') is not a permanent magnet, and ~~said planar diaphragm located in said planar region and parallel with said planar region, said diaphragm having a plurality of conductors on its planar surface for inducing electromagnetic forces acting on theses conductors in said planar region when current flows through said conductors~~
- that :

said conductors (108) on said diaphragm (100) are arranged in a pattern in relation to said magnetc field (104) strength through said diaphragm (100), said relation being such that said electromagnetic force acting on said conductors (108) is directed substantially normal to said surface of said planar diaphragm (100).

2. Diaphragm transducer according to claim 1, characterised in that said conductors (108) are arranged in a pattern with varying mutual distances and directions.

3. Diaphragm transducer according to claim 1 or 2, characterised in that said magnetic field (104) ~~in said planar region~~ through said diaphragm (100) is approximately constant.

4. Diaphragm transducer according to any one of the claims 1 - 3, characterised in that said magnetically conducting material (106, 106', 107, 107') is configured as plates, between which permanent magnets (102) are located, where one edge of each of said plates constitutes a magnetic pole for providing field strengh through said diaphragm (100).

~~2. Diaphragm transducer according to claim 1, characterised in that said magnetically conducting material is soft iron~~

~~3. Diaphragm transducer according to claim 1 or 2, characterised in that said magnetic field in said planar region is approximately constant.~~

~~4. Diaphragm transducer according to claim 1 - 3, characterised in that said magnetically conducting material is configured as plates, between which permanent magnets are located, where one edge of each of said plates constitutes a magnetic pole in said configuration.~~

5. Diaphragm transducer according to claim 4, characterised in that the number of poles are at least three with two outer poles (106, 106') and at least one inner pole (107).

6. Diaphragm transducer according to claim 5, characterised in that said number of inner poles located between the outer poles (106, 106') is at least two, where said inner poles (107, 107') are arranged in pairs of poles with a distance (103) between the two plates (107, 107') constituting said pair.

7. Diaphragm transducer according to claim 6, characterised in that said distance (103) between ~~the~~ said two plates (107, 107') constituting a pair of poles, is between 0.1 and 3 mm, preferably between 0.3 and 1.5 mm and preferably between 0.4 and 0.6 mm.

8. Diaphragm transducer according to any one of the claims 1- 7, characterised in that said magnetically conducting material (106, 106', 107, 107') is soft iron

~~8. Diaphragm transducer according to claim 1 - 7, characterised in that said conductors are oriented and connected such that, when current flows through said conductors, said electromagnetic forces acting on said conductors in said planar region are approximately in the same direction.~~

9. Diaphragm transducer according to any one of the - claims 1- - 8, characterised in that said diaphragm (100) comprises a magnetically conducting layer.

10. Diaphragm transducer according to claim 9, characterised in that said magnetically conducting layer (106, 106', 107, 107') comprises at least one from the group consisting of a coating with soft iron and a coating with Permalloy.

Replacement Sheet
13/9 2001

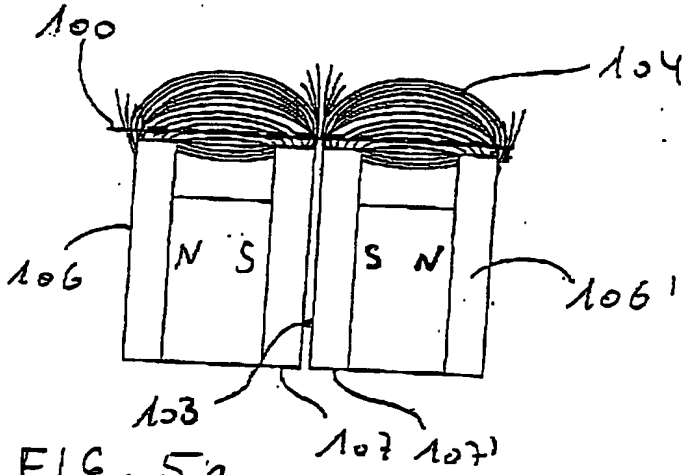

FIG. 5a

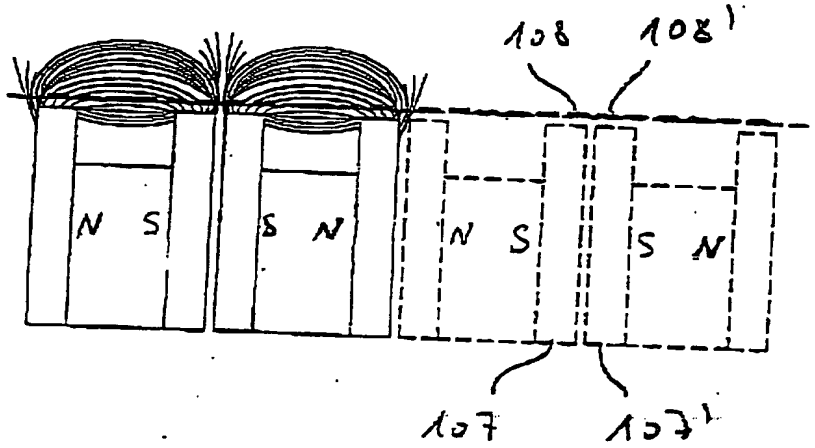

FIG. 5b

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 23 May 2001 (23.05.01)	
International application No. PCT/DK00/00504	**Applicant's or agent's file reference** P9961PC00
International filing date (day/month/year) 13 September 2000 (13.09.00)	**Priority date** (day/month/year) 14 September 1999 (14.09.99)
Applicant REENBERG, Nils, Peter	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

29 March 2001 (29.03.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Nestor Santesso
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 00/00504

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04R 7/00, H04R 9/00, H04R 9/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4491698 A (LARSON ET AL.), 1 January 1985 (01.01.85), page 6, line 13 - line 25	1,3-5,8
Y		2,6,9
	--	
Y	US 4354066 A (NECOECHEA), 12 October 1982 (12.10.82), page 5, line 26 - line 28; page 5, line 18 - line 24	2,6
	--	
Y	US 5297214 A (BRUNEY), 22 March 1994 (22.03.94), page 6, line 10 - line 14	9
	--	
A	US 5627903 A (PORRAZZO), 6 May 1997 (06.05.97)	1-9
	--	

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 December 2000	20 -12- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Mariana Eddin/OGU Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 00/00504

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9820705 A1 (CERWIN VEGA, INC.), 14 May 1998 (14.05.98)	1-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

04/12/00

International application No.
PCT/DK 00/00504

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4491698 A	01/01/85	AT 36924 T	15/09/88
		AU 563312 B	02/07/87
		AU 1777783 A	16/01/84
		BR 8307405 A	17/07/84
		CA 1213032 A	21/10/86
		DE 3377888 D	00/00/00
		EP 0112383 A,B	04/07/84
		SE 0112383 T3	
		EP 0262406 A	06/04/88
		US 4703510 A	27/10/87
		WO 8400093 A	05/01/84
US 4354066 A	12/10/82	EP 0098895 A	25/01/84
US 5297214 A	22/03/94	US 4939784 A	03/07/90
		US 5148493 A	15/09/92
US 5627903 A	06/05/97	AU 1213299 A	22/04/99
		AU 7927094 A	01/05/95
		CA 2173580 A	13/04/95
		EP 0748576 A	18/12/96
		JP 9504921 T	13/05/97
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		AU 5252898 A	29/05/98
		US 6111970 A	29/08/00
		WO 9820703 A	14/05/98